Operations Research and Analysis

Preliminary Report 7:

Terminal-Area Impacts of VHF Voice Radio Frequency Unavailability

January 1998

Prepared by:
William E. Weiss, CSSI Inc.
Art Politano, FAA

Prepared for:
Operations Research and Analysis Branch, ASD-430
Investment Analysis and Operations Research
Washington, D.C. 20591

In support of the
NEXCOM Investment Analysis Team

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1. Introduction

Under the Very High Frequency (VHF) voice communications system presently used by FAA Air Traffic Controllers and pilots, the number of available frequencies has decreased as air traffic has increased across the National Airspace System. In some areas, and in some busy metropolitan areas in particular, there are few or no radio frequencies available.

In addition, major airports in these and other areas are planning new runways that will greatly increase airport capacity. However, new radio frequencies will be required in each case to control traffic to and from the new runways. If radio frequencies were not available to direct air traffic to those new runways when they open, the runways would not be available for use by controlled traffic.

An investment analysis has been performed on the potential FAA acquisition called NEXCOM, a new generation of air-to-ground communications equipment that, if implemented, will greatly increase the number of available VHF radio voice frequencies. The analysis described in this report is part of the larger NEXCOM investment analysis. In this analysis, we estimate the benefits of upcoming major airport improvements that may be lost due to radio-frequency shortages. Given that NEXCOM will increase the number of available radio frequencies, the frequency shortages presumably would not occur if NEXCOM were implemented.

The approach taken was to locate terminal areas in which there are or will be VHF radio frequency shortages and where major airport improvements are planned. Because there was very little data available on radio frequency shortages, many discussions were held with FAA spectrum engineers and air traffic operations staff at FAA headquarters, FAA Regional offices, and at FAA facilities. Once these discussions clarified whether frequencies are or will be available, FAA Airport Capacity Enhancement Plans for airports in those terminal areas were examined. The plans were downloaded from the FAA's Office of System Capacity (ASC) Web site at "http://www.asc.faa.gov/". These plans document the airport-capacity-enhancement studies sponsored by the FAA Office of System Capacity and performed by staff at the FAA Technical Center. Simulation studies of the effects of various airport improvements on present and future operations, and the resulting estimates of benefits, are documented in these plans.

Because it is not clear that *all* new-runway benefits would be lost if there were no frequencies available, FAA staff at the Atlanta (ATL) and Minneapolis (MSP) Air Traffic Control Towers were consulted on how they would mitigate the effects of a frequency shortage. Also, discussions were held with FAA ASC staff regarding the size of the new-runway benefits quoted in the Capacity Enhancement Plans.

In the remainder of this report, the study findings are summarized in Section 2, the improvements and benefits for specific airports are described in Section 3, and caveats are listed in Section 4.

2. Findings

2.1. Summary

The total estimated benefits of the new runways described in Section 3 are worth $8.9 Billion in 1997 dollars. These benefits are due to operational efficiencies and delay decreases resulting from the planned new runways. The benefits are for the time period beginning with the completion of each new runway and ending with the year 2015. Benefits at two airports, Cincinnati and Los Angeles, could not be quantified because studies with quantified benefits were not available. Table 1 summarizes the information obtained in this analysis, along with the estimates of the new-runway benefits.

Table 1. Summary of Findings: Benefits of Planned New Runways

Airport	Planned Improvement	Average Annual/Total Benefit	Level of Confidence in Frequency Shortage	Caveats
Atlanta	Parallel runway in 2001	$456M/$6.841B	High	Enhancement Plan states that these benefits may be overstated.
Charlotte	Parallel runway in 2001	$50M/ $747M	High	Dependent operations assumed on new runway (conservative assumption)
Cincinnati	Parallel runway in 2004	Not available	High	Recent frequency requests turned down
Cleveland	Parallel runway in 2001	$20M/ $294M	High	Traffic growth outpaced TAF estimates; airport consultant's growth predictions used.
Los Angeles	Parallel runway in 2006	Not available	High	Position and length of new runway not yet final
Minneapolis	New runway in 2003	$78M/ $1.010B	High	PRM override switch will free two frequencies, but opposed by user group

All of the benefits cited in Table 1 were derived from benefits estimates listed in FAA Airport Capacity Enhancement Plans; they have been converted to 1997 dollars for consistency, interpolated between estimates given in the plans, and extrapolated out to 2015.

The benefits in Table 1 will be enabled not only by each new runway, but by other airport and ATC factors as well. Many factors enable new-runway benefits to some extent, including the runway itself, taxiways, airport and approach lighting, the instrument landing system, airport signs, voice radio frequencies, and airspace, among others. In examining these factors, we estimated that between 3.5 and 23.5 percent of the benefits could be attributed to voice radio frequency availability, with a most likely attribution of 13.5 percent.

2.2. Mitigating Frequency-Shortage Effects

Although it is clear that air traffic cannot be controlled to a new runway at a major airport without the needed voice radio frequencies, it is also clear that air traffic facility staff will ensure that the new runway will generate as many benefits as possible. Put simply, facility staff will do as much as possible to "minimize the pain" of the frequency shortage, if at all possible.

When questioned, FAA Southern Region air traffic operations staff said that their most likely approach to mitigate the effects of a frequency shortage on new-runway operations at Atlanta would be to "shuffle" or reengineer radio frequencies to maximize the benefits of the new runway. Less-used frequencies would be combined or shifted to free-up frequencies for traffic to and from the new runway. Satellite sectors might be combined, for example, making frequencies available for the new runway but creating delays to air traffic destined for satellite airports. Effectively, aircraft in other parts of the airspace will encounter increased delays as a result of sacrificing frequencies for traffic to and from the new runway.

On the other hand, MSP operations staff said that there is no more radio-frequency shuffling that can be done. They reiterated that there will be no benefit to the new runway if their frequency shortage is not resolved.

In addition, there may be other detrimental effects of "shuffling" radio frequencies. In some areas, the Los Angeles Basin in particular, there are already virtually no radio frequencies available, and those in use are carefully placed from a geographic standpoint to avoid interference between frequencies. Shifting the volume of airspace served by a frequency, or, even worse, shifting many frequencies, may create radio-frequency interference (RFI) and other communications problems. In a crowded radio communications environment, these problems can literally take years to overcome. The cost of these problems has not been estimated in this report.

2.3. Capacity Enhancement Plan Benefits Estimates

The benefit estimates cited in this report are taken from Capacity Enhancement Plans; these are estimates of the delays that would be avoided if the airport's capacity is increased because of the new runway. Because of the high value of the benefits attributed to the new runways in the Capacity Enhancement Plans, ASC staff were consulted on the accuracy of those benefits. ASC staff estimated that the benefits estimates given in the Capacity Enhancement Plans were not conservative and in fact may be too high because of the way future airport operations were simulated.

The delay benefits were estimated by determining the difference between simulated delays for a baseline case and a new-runway case at future demand levels. In the baseline case, aircraft delays were higher than in the new-runway case. However, in each case, delays were not "capped." That is, delays rose without limit as the airport attempted to accommodate the simulated traffic. In a real operational environment, delays are "capped," usually through airline procedures. That is, once delays rise to a certain level, airlines take remedial measures, such as diverting and rescheduling flights.

The difficulty in simulating such a situation is in not knowing how high delays will rise before the airlines take remedial measures. And each airline, obviously, is likely to have a different threshold for taking measures. Because it was difficult, if not impossible, to accurately simulate these actions with existing simulation tools, they were not simulated, and all demand on the airport was accommodated, resulting in very high delays. When demand is so much higher than capacity, as in the baseline case, *simulated* delays are likely to be higher than delays would be in reality. This is less likely to be true for the new-runway case because the additional capacity resulting from the new runway will keep delays down to more realistic levels. The end result is that the difference in delays between the two cases, and thus the benefits estimate, is likely to be higher than it would be in reality.

Two related factors also affect delay benefits: the first is latent demand, which would inflate the expected delays in the new-runway case. That is, airlines typically schedule additional flights into desirable destinations when the airport capacity increases (due to a new runway, for example). Given that airlines do this, the difference between the delay estimates for the baseline and new-runway cases is likely to be smaller (since delays will go up in the new-runway case due to the added demand). The second factor is this: the airlines will generate considerable revenue as a result of the added flights, and this revenue could be considered a benefit of the new runway.

In summary, then, the delay benefits estimates given in the Capacity Enhancement Plans are not conservative and in fact may be too high. However, airlines may derive additional benefits from new flights added as a result of the increase in airport capacity; these benefits could also be attributed to the new runway. These benefits are not documented in either the Capacity Enhancement Plans or in this report.

2.4. Attribution of Benefits

As Section 2.3 of this report indicates, the new-runway benefits were obtained by estimating the value of the delays that would be avoided if the airports' capacity were increased because of the new runway. These benefits are enabled by many contributing factors, including:

1. The runway itself

2. Instrument landing system equipment and its radio frequencies
3. Lighting, including approach, threshold, edge, centerline, touchdown zone, and taxiway
4. Available VHF voice radio frequencies
5. Available airspace for arriving and departing traffic
6. Taxiways and runway exits
7. Airport signs
8. Other factors

However, because this report is concerned with impacts of VHF voice radio frequency unavailability, it is necessary to estimate the portion of the benefits that can be attributed to the VHF voice frequencies required to direct traffic to and from the new runway. That is, given above list of contributing factors, how much of the delay benefits can be attributed to radio frequency availability?

The question is difficult to answer. Benefits might be attributed by considering radio frequency availability on a marginal basis, or as one factor in the group of factors required to obtain the benefits.

If one attempts to attribute benefits on a marginal basis, one could argue that the benefit of having needed frequencies available would be the avoided cost of reengineering the frequencies (for the cases where reengineering would solve the problem), plus the benefits of the ATC services made available by those frequencies. That is, if a procedural work-around could solve the lack-of-frequencies problem at an airport without adding a frequency, then the radio-frequency benefits would be the total cost (including the cost to users) of that work-around. However, this argument is based on the assumption that the frequencies required for a new runway at a major airport will somehow be found, perhaps at the expense of other, lower-priority ATC services. The benefits of the new frequencies, if they were available, would be the cost of the alternative: namely, the cost to users of the sacrificed services and/or the cost to the FAA of the required work-around. More effort would be required to quantify these costs.

If one attempts to attribute benefits by considering all the contributing factors as a whole, one could argue that attribution of benefits must recognize all of the enabling factors to avoid double counting, and so that a consistent approach can serve future decisions on other programs as well.

In the list above, we identified the factors that would enable the avoided-delay benefits of a new runway. We know that no benefits would occur without the new runway itself, so that can be considered the most important factor. Factors 2 and 3 are critically important during instrument meteorological conditions (IMC). Although we know that these conditions occur an average 13 percent of the time, the vast majority of delays occur in IMC. In fact, the 1997 FAA Aviation Capacity Enhancement Plan says that 75 percent of the delays greater than 15 minutes occur in IMC. Therefore, it makes sense to weight the attribution of benefits this way: those factors contributing to IMC operations would receive, in total, 75 percent of the benefits, and those factors contributing to visual meteorological conditions (VMC) operations would receive 25 percent of the benefits.

VMC benefits can be attributed in the following manner: first, because the runway is without question the most important factor, we attribute 50 percent of the IMC benefits to the runway. No benefits are attributed to the ILS, its associated lights, and its radio frequencies because they are not essential in VMC. The remaining 50 percent of VMC benefits are split between the VHF voice frequencies, airspace availability, taxiways/exits, and airport signs, with the emphasis on the first two factors. These attributions are shown in column two of Table 2.

Table 2. Attribution of Benefits

Delays	VMC Benefits (25% Weight)	IMC Benefits (75% Weight)	Total Weighted Benefits
Runway	50.0%	50.0%	50.0%
ILS/Frequencies/Lights		25.0%	18.8%
Voice Frequencies	16.7%	12.5%	13.5%
Airspace	16.7%	4.2%	7.3%
Taxiways/Exits	8.3%	4.2%	5.2%
Signs	8.3%	4.2%	5.2%
	100.0%	100.0%	100.0%

IMC benefits can be attributed in the following manner: as in VMC, we attribute 50 percent of the IMC benefits to the runway. Then, because the ILS, its associated lights, and its radio frequencies *are* essential in IMC, we attribute half of the remaining benefits to those factors. We then attribute half of the remaining benefits, or 12.5 percent, to voice frequencies. Finally, we divide the remaining benefits evenly among the remaining factors. These attributions are shown in column three of Table 2. The total weighted benefits are shown in column four of Table 2.

At best, this approach is a starting point. It may overstate the benefits attributable to radio frequency availability, as proponents of the marginal approach might suggest by pointing to the probability of reengineering existing frequencies.

Obviously, the attribution of benefits using this method is somewhat arbitrary. To eliminate some of this aspect, we assume that the availability of VHF radio frequencies may vary in importance by 10 percentage points either way, with other factors compressing or expanding proportionately. The benefits attributed to radio frequencies, then, could be a minimum of 3.5 percent and at most 23.5 percent, with a middle value of 13.5 percent.

2.5. Conclusions

Although new runways and radio-frequency shortages were only investigated in the FAA's Southern and Great Lakes Regions, as well as in the Southern California area, it is reasonable to assume that there are, or soon will be, frequency shortages in other terminal areas. And, of course, other major airports are planning new runways that will require additional radio frequencies. Thus, the total benefits that would be enabled by additional radio frequencies, may, in fact, be larger than those cited in this report. To more completely describe the benefits that would be enabled by new frequencies, further investigation is warranted of improvements at major airports and of other areas that lack frequencies.

Because radio frequencies are not available at the airports we examined, it is natural to nominally attribute the delay benefits to the provision of those frequencies. No cause-and-effect relationship is implied in this report. In fact, new-runway benefits may be partially claimed by other factors, such as construction of the runway itself, the runway exits and taxiways, airport lighting, instrument landing systems, airspace availability, and other factors. The extent of the role played by frequency availability is a good topic for further study. Given an evaluation of the runway benefits as a whole, we estimate that about 13.5 percent of the benefits could be attributed to radio frequency availability, give or take 10 percent.

Moreover, the actual benefits of the new runways described in this report will most likely not be as great as the benefits cited, for two reasons:

- Air traffic staff will take steps to mitigate the effects of frequency shortages. The effect of this mitigation will be to reduce the benefits of the new runway as a result of a frequency shortage.
- Due to simulation limitations, the benefits of the new runways described in this report are overstated.

However, there may be other benefits, such as increased revenue from airline flights added because of the new runways, that are not cited in this report.

3. Airport Results

3.1. Atlanta

Construction has begun on a fifth parallel runway at Hartsfield Atlanta International Airport (ATL). This runway is scheduled to be completed in 2001, and will allow independent parallel Instrument Flight Rules (IFR) operations to Stage 3 aircraft of less than 100,000 pounds maximum gross landing weight. Although this runway will be separated from the nearest parallel runway by less than 4,300 feet, a Precision Runway Monitor (PRM) will allow controllers to direct an independent stream of traffic to the new runway.

3.1.1. Frequency Requirements

FAA Southern Region staff have indicated that at least four new frequencies will be needed to control arrivals and departures onto and off of the new runway:

1. Arrival
2. Final Approach
3. Local
4. Ground

Two other frequencies may be needed for the new runway. Currently, ATL has two ATIS (Automated Traffic Information Service) frequencies: one for arrivals, and one to supply departures with information such as departure runway names and radio frequencies. An additional ATIS frequency may be required for the new runway. Also, although the new runway is initially slated for arrivals only, if departures are to be released off that runway, a new departure frequency will be required.

Staff at FAA's Southern Region Airways Facilities Division Operations Branch (ASO-470) indicate that there are *no* frequencies available at this time. Thus, it can be assumed that there will certainly *not* be up to six frequencies available for the new runway by the time it opens. Southern Region operations staff have indicated that frequencies may be "shuffled" to free frequencies for traffic to the new runway, but that this would be at the expense of other traffic. (See Section 2 of this report.) Therefore, because the new runway may not become operational without additional radio frequencies (or other air traffic in the area will encounter increased delays), and because those frequencies will not become available unless NEXCOM is acquired and implemented, then at least some of the delay-reduction benefits due to the new runway can be attributed, at least in part, to NEXCOM.

3.1.2. New Runway Benefits

A Capacity Enhancement Plan Update for ATL was completed in 1995. (This plan can be found on the World Wide Web at http://www.asc.faa.gov/.) This update of the 1987 Capacity Enhancement Plan was prepared jointly by the U.S. Department of Transportation, the Federal Aviation Administration, the City of Atlanta Department of Aviation, and the airlines and general aviation serving Atlanta. In this update, delay savings due to the use of the new runway were estimated.

The delay savings varied depending on the taxiway plan used for the new runway. In the first option, aircraft taxied on a perimeter taxiway, avoiding operations on the existing runways 9L and 9R. (This option would be most advantageous because aircraft from the new runway would not be required to cross an active runway.) In the second option, aircraft taxied around the end of runway 9R and then down between the two runways before crossing runway 9L. In the final option, aircraft crossed both runway 9L and 9R. When consulted, airport planning staff from the City of Atlanta Department of Aviation confirmed that the most likely alternative is the second option, aircraft crossing one active runway. Thus, the delay savings for the second option are listed in Table 3 below.

These delay savings were predicted for a baseline demand (700,000 annual operations) and for two future levels of demand not associated with specific years, called Future 1 (850,000 operations) and Future 2 (1,000,000 operations).

Table 3. Estimated Annual Delay Savings Due to 5th Parallel Runway at ATL

Demand Level	Year	Predicted Annual Operations	Delay Savings (1997 $millions)
Baseline	**1994**	**699,400**	***$27.11***
	1995	747,105	*$60.84*
	1996	855,197	*$94.56*
Future 1 (roughly)	**1997**	**855,197**	**$128.29**
	1998	870,615	*$158.09*
	1999	886,035	*$187.88*
	2000	901,454	*$217.68*
	2001	916,874	*$247.47*
	2002	932,293	*$277.27*
	2003	947,712	*$307.06*
	2004	963,132	*$336.86*
	2005	978,551	*$366.65*
	2006	993,970	*$396.45*
Future 2 (roughly)	**2007**	**1,009,390**	**$426.25**
	2008	1,024,809	*$456.04*
	2009	1,040,229	*$485.84*
	2010	1,055,649	*$515.63*
	2011	1,071,069	*$545.43*
	2012	1,086,489	*$575.22*
	2013	1,101,909	*$605.02*
	2014	1,117,329	*$634.81*
	2015	1,132,749	*$664.61*

Table 3 requires some explanation. The predicted annual operations were derived from the on-line version of the FAA Terminal Area Forecasts (on the Web at http://api.hq.faa.gov/ftp/taf1_dat.exe). The values listed in gray print above the double line at the top of the table are listed for completeness but are not relevant to any benefits calculation because the runway will not be finished until 2001. The delay savings shown in boldface are those given in the Capacity Enhancement Plan Update for the demand levels listed. Those in italics have been linearly interpolated between the given values. Note that an exponential, rather than linear, growth rate in delays would be expected given a linear growth rate in traffic; however, a linear rate has been used here as a conservative approximation. The final delay-savings values, for the years 2008 through 2015, have been extrapolated using the same growth rate for the years between Future 1 and Future 2. Airport operators frequently close existing runways for reconstruction at the time a new runway opens; if this is the case when ATL's new runway opens, benefits from the new runway would be delayed until all runways are open.

Finally, and most importantly, the Capacity Enhancement Plan Update points out that the SIMMOD-generated benefits values must be viewed as **highly optimistic estimates** because it is expected "that the numerous operating practices and complexities associated with a heavy ATC workload during an arrival and departure push would result in **significantly lower estimated savings** and greater delay estimates" (emphasis added for this report). Also, due to the simulation limitations described in Section 2, these new-runway benefits are probably overstated.

3.2. Charlotte Douglas

The Aviation Department of the City of Charlotte, North Carolina plans to open a new, air-carrier length runway at Charlotte Douglas International Airport (CLT) in 2001. This runway will be parallel to the existing pair of 18/36 parallel runways and will be separated from the westernmost of the existing runways by 3,750 feet. This separation will allow CLT to operate triple parallel IFR approaches when the new runway opens, with two independent and one dependent streams of arrivals. Other, future technologies, such as automatic dependent surveillance-broadcast (ADS-B) coupled with cockpit displays of traffic information (CDTIs), may allow three independent streams of traffic into CLT with its new runway. Another option for three independent streams would be the installation of a precision runway monitor (PRM). However, there are no plans at this time for acquiring and installing one at CLT.

3.2.1. Frequency Requirements

In 1997, ASO staff turned down a CLT request for three new VHF voice frequencies because there are no frequencies available at CLT. The opening of the new runway is likely to require a minimum of three new frequencies for approach, departure, and ground control, and may require more (for an additional ATIS, for example). Given that there are no frequencies available to satisfy current requirements at CLT, it is reasonable to assume that no frequencies will be available when the runway opens in 2001.

3.2.2. New Runway Benefits

Because ADS-B/CDTI approaches are not beyond the "concept" stage, and given that there are no plans to install a PRM at CLT, it is reasonable and conservative to assume that the most likely operating configuration when the new runway opens will be two independent and one dependent streams of IFR traffic. Table 4 shows the estimated delay savings due to the new runway.

Table 4. Estimated Annual Delay Savings Due to New Runway at CLT

Demand Level	Year	Predicted Annual Operations	Delay Savings (1997 $millions)
	1997	482,788	$21.82
	1998	492,510	$23.03
	1999	502,395	$24.24

	2000	512,595	$25.45
Future 1	**2001**	**522,680**	**$26.66**
	2002	533,056	*$29.96*
	2003	543,730	*$33.26*
	2004	554,711	*$36.57*
	2005	565,973	*$39.87*
	2006	575,567	*$43.17*
	2007	585,399	*$46.47*
	2008	595,475	*$49.77*
Future 2	**2009**	**605,825**	**$53.07**
	2010	616,427	*$56.37*
	2011	626,518	*$59.67*
	2012	636,609	*$62.97*
	2013	646,699	*$66.27*
	2014	656,790	*$69.57*
	2015	666,881	*$72.87*

Table 4 is comparable to Table 3 above. The values listed in gray print above the double line at the top of the table are listed for completeness but are not relevant to any benefits calculation because the runway will not be finished until 2001. The delay savings shown in boldface are those given in the Capacity Enhancement Plan for the demand levels listed. (These delay savings have been converted to 1997 dollars to be consistent.) Those in italics have been linearly interpolated between the given values. Note that an exponential, rather than linear, growth rate in delays would be expected given a linear growth rate in traffic; however, a linear rate has been used here as a conservative approximation. The final delay-savings values, for the years 2009 through 2015, have been extrapolated using the approximately the same growth rate for the years between Future 1 and Future 2. Airport operators frequently close existing runways for reconstruction at the time a new runway opens; if this is the case when CLT's new runway opens, benefits from the new runway may be delayed until all runways are open. Also, due to the simulation limitations described in Section 2, these new-runway benefits are probably overstated.

3.3. Cincinnati

Cincinnati is another area in which there are no available VHF frequencies. The TRACON staff at Cincinnati/Northern Kentucky International Airport (CVG) requested two VHF frequencies in 1997 and were turned down following an analysis by ASO staff.

CVG provides an example of a situation that is typical in areas where there are few or no frequencies available. After a facility's request for a new frequency (or frequencies) is turned down, the facility's staff investigate frequency use in their area, looking for under-utilized frequencies. In this case, CVG staff are investigating whether a frequency presently "owned" by

Cincinnati Municipal Airport-Lunken Field (LUK) may be available. If so, it may be transferred for use by CVG to satisfy its more critical need.

CVG requires these frequencies for two new approach-control positions. Although one position would be for satellite airports, the more critical position would be for a full-time, third arrival position.

CVG has two parallel runways and a crosswind runway that intersects one of the parallels at an angle of 90 degrees. In visual flight rules (VFR) conditions, CVG runs either one arrival stream into each of the three runways, or runs three departure streams off of the two parallel runways. Six positions would be required to run both the three arrival and three departure streams simultaneously, but there are VHF frequencies available for only five of these positions. Hence, if the frequency can be transferred from LUK, it would be used for a third full-time arrival position, enabling the simultaneous control of three arrival and three departure streams.

CVG operational staff indicated that, at present demand levels, they can "maintain pressure on the concrete," meaning that the overall capacity of the airport and airspace is not limited by the lack of the full-time arrival position. However, this may not continue to be case as demand increases in the future. And, controller workload is certainly increased by the lack of this frequency.

Also, the CVG airport operator is planning a third parallel runway which may open as early as 2004, depending on growth in demand and the results of the Environmental Impact Study. There will be demand for additional frequencies to service traffic to that runway. Thus, if those frequencies cannot be supplied, then airport capacity *will* be limited by lack of VHF frequencies. A delay study is in progress at this writing; the delay and monetary benefits of the new runway may be available on its completion.

3.4. Cleveland Hopkins

A new runway, parallel to and west of the existing set of 5/23 parallels, will be built at Cleveland Hopkins International (CLE). Phase I, the first 6,500 feet, should be completed by 2001. Phase II, a significant extension, should be completed by 2004.

The largest operator at CLE is Continental Airlines, whose fleet mix at CLE is 50 percent propeller-driven aircraft. Even though these are scheduled to be replaced by regional jets, the fleet mix contains, and will contain in the future, enough smaller aircraft to allow full utilization of the new runway at its initial 6,500-foot length.

Traffic has grown very quickly at CLE; 320,000 operations have been estimated for 1997. In the 1994 Capacity Enhancement Plan, 322,500 operations were listed as the "Future 2" level of operations. According to the TAF, CLE was predicted to reach 320,000 annual operations in

2003. A current prediction, obtained from the airport's engineering consultant, is that CLE will reach 500,000 operations 20 years from now.

3.4.1. Frequency Requirements

According to Planning and Procedures staff at CLE Tower, there are no available frequencies at this time, and several are needed:

- ?? Two approach control
- ?? One ATIS
- ?? One tower feeder position (for winter months only)

Four additional frequencies will be required for the new runway:

- ?? Departure
- ?? Arrival
- ?? Ground
- ?? ATIS

3.4.2. New Runway Benefits

Because operations have already reached the level predicted in the TAF for 2003, the prediction of 500,000 operations in 20 years will instead be used as a basis for future growth and delay savings. Assuming linear growth, this yields an annual growth rate of 2.4 percent, which is conservative when compared to recent growth at CLE. (Operations grew 5.2 percent from FY93 to FY94, and 9.8 percent from FY94 to FY95. Operations grew 11.8 percent from FY95 to FY97. Operations figures were not available for FY96.) Table 5 shows the benefits associated with the new runway at CLE using this growth rate.

Table 5. Estimated Annual Delay Savings Due to New Runway at CLE

Demand Level	Year	Predicted Annual Operations	Delay Savings (1997 $millions)
Future 2	**1997**	**320,000**	**$15.08**
	1998	327,605	*$15.44*
	1999	335,392	*$15.81*
	2000	343,363	*$16.18*
	2001	351,523	*$16.57*
	2002	359,878	*$16.96*
	2003	368,431	*$17.37*
	2004	377,188	*$17.78*
	2005	386,152	*$18.20*
	2006	395,330	*$18.63*

2007	404,725	*$19.08*
2008	414,344	*$19.53*
2009	424,192	*$19.99*
2010	434,274	*$20.47*
2011	444,595	*$20.96*
2012	455,162	*$21.45*
2013	465,980	*$21.96*
2014	477,054	*$22.49*
2015	488,392	*$23.02*

Table 5 is comparable to Tables 3 and 4 above. The values listed in gray print above the double line at the top of the table are listed for completeness but are not relevant to any benefits calculation because the runway will not be finished until 2001. The delay savings shown in boldface are those given in the Capacity Enhancement Plan for the demand level listed. (These delay savings have been converted to 1997 dollars to be consistent.) Those in italics have been linearly extrapolated at the same growth rate (2.4 percent) as the traffic growth rate, which is a very conservative assumption. (The traffic growth rate was obtained from Cleveland's airport consultant. The TAF growth rate could not be used because growth at CLE has already far exceeded TAF estimates.) Note that an exponential, rather than linear, growth rate in delays would be expected given a linear growth rate in traffic; however, a linear rate has been used here as a conservative approximation. Airport operators frequently close existing runways for reconstruction at the time a new runway opens; if this is the case when CLE's new runway opens, benefits from the new runway may be delayed until all runways are open. Also, due to the simulation limitations described in Section 2, these new-runway benefits are probably overstated.

3.5. Los Angeles

The Los Angeles Basin has very busy airspace with radio problems that include tunneling, radio-frequency interference (RFI), and frequency shortages. According to AWP-470 staff, the L.A. Basin is a very fragile radio-frequency environment, where even small changes can induce RFI that takes years to reduce. Adding a new frequency in the L.A. Basin, even where one might be available, raises the "noise floor" for all radio frequencies in the Basin; if frequencies continue to be added, less sensitive radio receivers may become unusable.

These problems are most acute near Los Angeles International Airport (LAX). According to AWP-470 staff, there are no frequencies available at LAX that meet the criteria required for a new radio frequency. There are plans to build a new runway at LAX that will become operational between years 2005 and 2010. The last Los Angeles Airport Capacity Task Force did not address the benefits of a new runway, so no monetary benefits are available at this time. However, a delay study for the new runway is currently in progress; estimates of monetary benefits should be available once it's completed. Because Los Angeles is the nation's fourthbusiest airport, the monetary benefits of a new runway there are likely to be tremendous. These benefits will not occur if new radio frequencies do not become available and if the frequency problems in the L.A. Basin are not solved.

3.6. Minneapolis

3.6.1. Frequency Requirements

The Minneapolis TRACON has no spare frequencies and needs one additional ground control frequency at this time.

The west ground and west local frequencies at Minneapolis-St. Paul International (MSP) were shifted for use with the recently installed Precision Runway Monitor (PRM). There is presently no communications-frequency override switch installed for the PRM; if this is installed, it will free two voice channels. However, a user group is lobbying against the override switch and its installation is now in doubt.

MSP will also need additional frequencies in the near future due to airspace changes associated with a new runway expected to open in 2003. The following changes are expected:

- TRACON departures will be expanded from two to three, requiring an additional frequency.
- TRACON arrival streams will also be expanded from two to three, requiring an additional frequency.
- An additional traffic stream to satellite airports will require another frequency.
- The new runway at MSP will require new ground and local control frequencies.

The new runway will increase airport capacity 30% to 40%, but there will be no capacity increase without the required frequencies.

3.6.2. New Runway Benefits

The benefits of the new runway at MSP were calculated in the same manner as those for ATL described above. Table 6 lists those predicted benefits.

Table 6. Estimated Annual Delay Savings Due to New Runway at MSP

Demand Level	Year	Predicted Annual Operations	Delay Savings (1997 $millions)
Baseline	**1993**	**442,341**	**$10.87**
	1994	454,441	*$13.80*
	1995	466,916	*$16.73*
	1996	479,054	*$19.66*
	1997	489,251	*$22.59*
	1998	499,749	*$25.52*
	1999	509,946	*$28.46*
	2000	520,143	*$31.39*
Future 1 (roughly)	**2001**	**530,340**	**$34.32**
	2002	540,537	$39.75
	2003	550,734	*$45.17*
	2004	560,931	*$50.60*
	2005	571,052	*$56.02*
	2006	581,174	*$61.45*
	2007	591,296	*$66.87*
Future 2 (roughly)	**2008**	**601,422**	**$72.30**
	2009	611,630	*$77.72*
	2010	621,844	*$83.14*
	2011	632,002	*$88.57*
	2012	642,161	*$93.99*
	2013	652,319	*$99.41*
	2014	662,478	*$104.83*
	2015	672,636	*$110.26*

Table 6 is comparable to Tables 3 through 5 above. The values listed in gray print above the double line at the top of the table are listed for completeness but are not relevant to any benefits calculation because the runway will not be finished until 2003. The delay savings shown in boldface are those given in the Capacity Enhancement Plan for the demand levels listed (corrected to 1997 dollars). Those in italics have been linearly interpolated between the given values. Note that an exponential, rather than linear, growth rate in delays would be expected given a linear growth rate in traffic; however, a linear rate has been used here as a conservative approximation. The final delay-savings values, for the years 2009 through 2015, have been extrapolated using the same linear growth rate for the years between Future 1 and Future 2. Airport operators frequently close existing runways for reconstruction at the time a new runway opens; if this is the case when MSP's new runway opens, benefits from the new runway may be delayed until all runways are open. Also, due to the simulation limitations described in Section 2, these new-runway benefits are probably overstated.

4. Caveats

The benefits listed in this report are based on daily delays converted to annual delays. The daily delays were derived from computer simulations of airport or, in some cases, only runway operations.

In the ATL study, airfield activity was simulated, including operations on the runways, taxiways, ramp areas, and at the gates. Airspace activity in the immediate arrival and departure corridors was also simulated. Both the Runway Delay Simulation Model (RDSIM) and SIMMOD, the Airport and Airspace Simulation Model, were used in the analysis.

At CLE, the Airport Delay Simulation Model (ADSIM) and RDSIM were used. At CLT, RDSIM was used to model only runway operations, while at MSP, SIMMOD was used.

The benefits cited in this report are based on those found in Airport Capacity Enhancement Plans for specific airports. These plans were produced by FAA Technical Center staff and were sponsored by the FAA Office of System Capacity. For consistency in this report, the benefits listed in those Plans were translated into 1997 dollars using the inflation rate of the U.S. Consumer Price Index. The benefits listed in each plan were given only for three unspecified years called Baseline, Future 1, and Future 2. The FAA Terminal-Area Forecasts were used, for all airports but Cleveland, to apply specific years to the benefits estimates listed in the Plans. Benefits were then interpolated in a straight-line manner between those given in the plans. Benefits were also extrapolated in a straight-line manner out to the year 2015. Note that benefits do not include the value of passenger time or disruption of airline schedules. And again, it should be emphasized that the delay benefits estimates given in the Capacity Enhancement Plans are not conservative and in fact may be too high. (See Section 2 for a more complete explanation.)

It is important for the reader to note that the radio frequency shortages cited in this report are based on interviews with FAA Regional and facility staff, not on modeling or analysis done for this report. However, the sources interviewed for the frequency information are users of the models that determine if frequencies are available. Also, those sources are experts on the frequency situation at their individual locations. It is also important to point out that, at least in some terminal areas, “shuffling” or reengineering radio frequencies may enable at least *some* of the new-runway benefits. (Again, see Section 2.)

References

Charlotte/Douglas International Airport Capacity Enhancement Plan. Washington, D.C.: U.S. Department of Transportation, Federal Aviation Administration; April 1991. (http://www.asc.faa.gov/).

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